Stony Brook University

DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

3DST Group Meeting

3DST & TPC: First Look at a Sign Selected CC Inclusive Event Selection

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- The full spill simulation
  - ECal simulation is approximate, but not used
  - Both RHC and FHC studied
    - Simulation done on 21/02/25 (RHC)
- 3DST and TPC track matching
- Very simple sign selected CC inclusive selection

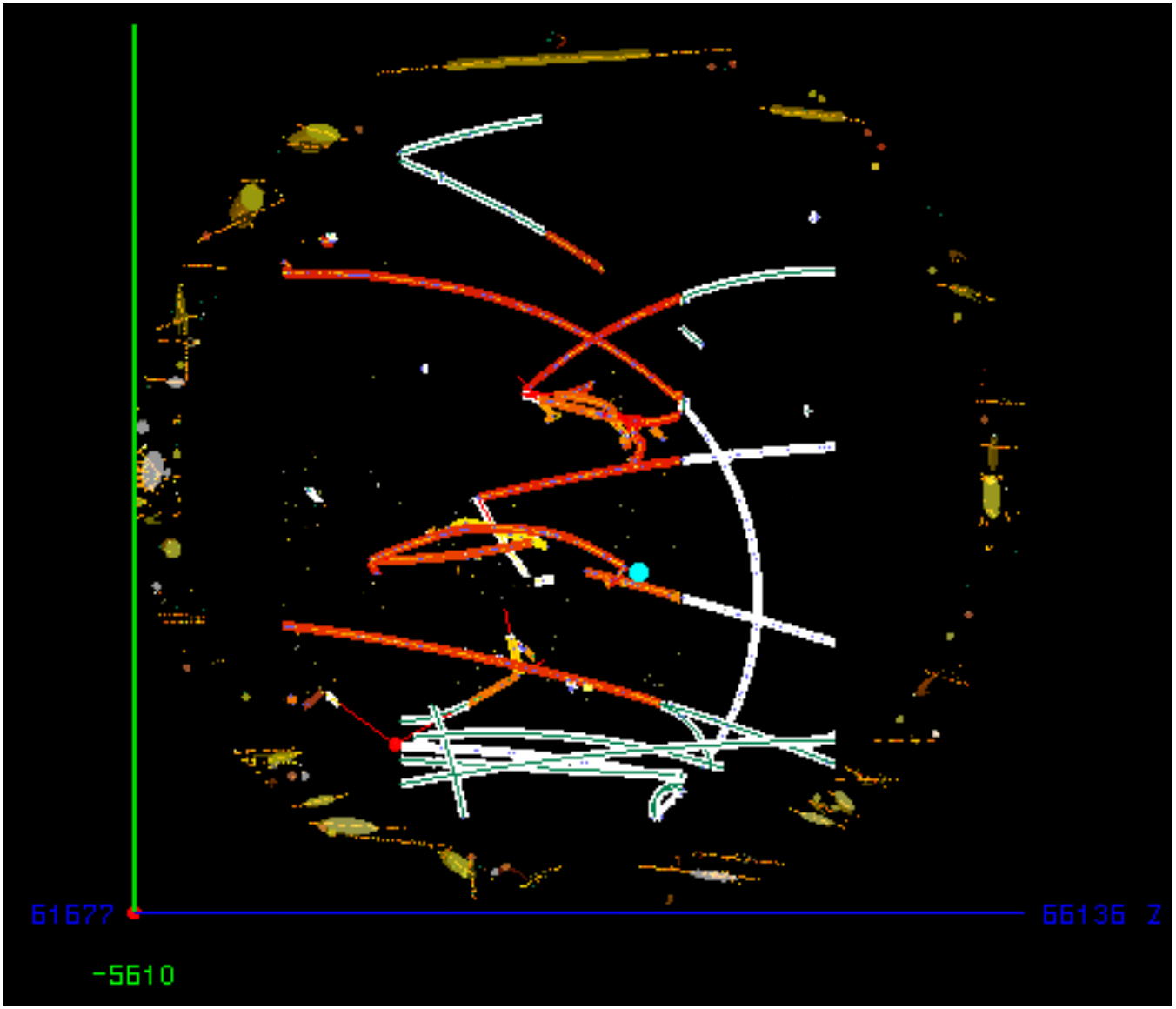
The Full Spill Simulation

- Use the full chain
  - GENIE:
    - FHC and RHC beam with 7.5×10^{13} POT per spill
      - 3.15×10^{17} POT simulated (4200 spills for each flavor)
    - Includes 250 m of rock upstream of hall
  - EDepSim:
    - Track all particles, but only save trajectories hitting sensitve detectors
  - sand-stt:
    - Simulate ecal response for each individual interaction
  - ERepSim:
    - Overlay interactions (e.g ~3500 per RHC spill).
    - Simulate 3DST and TPC
      - Overlay edep-sim results and simulate electronics response
    - Use sand-stt for ECal
      - Uses 400 ns integration, and does not include dead time and event overlap.
      - For each channel, sort hits by time, and combine hits within the targeted integration window (either 400ns or 30 ns).
  - CubeRecon
    - Already built to handle full spill, so just run it.

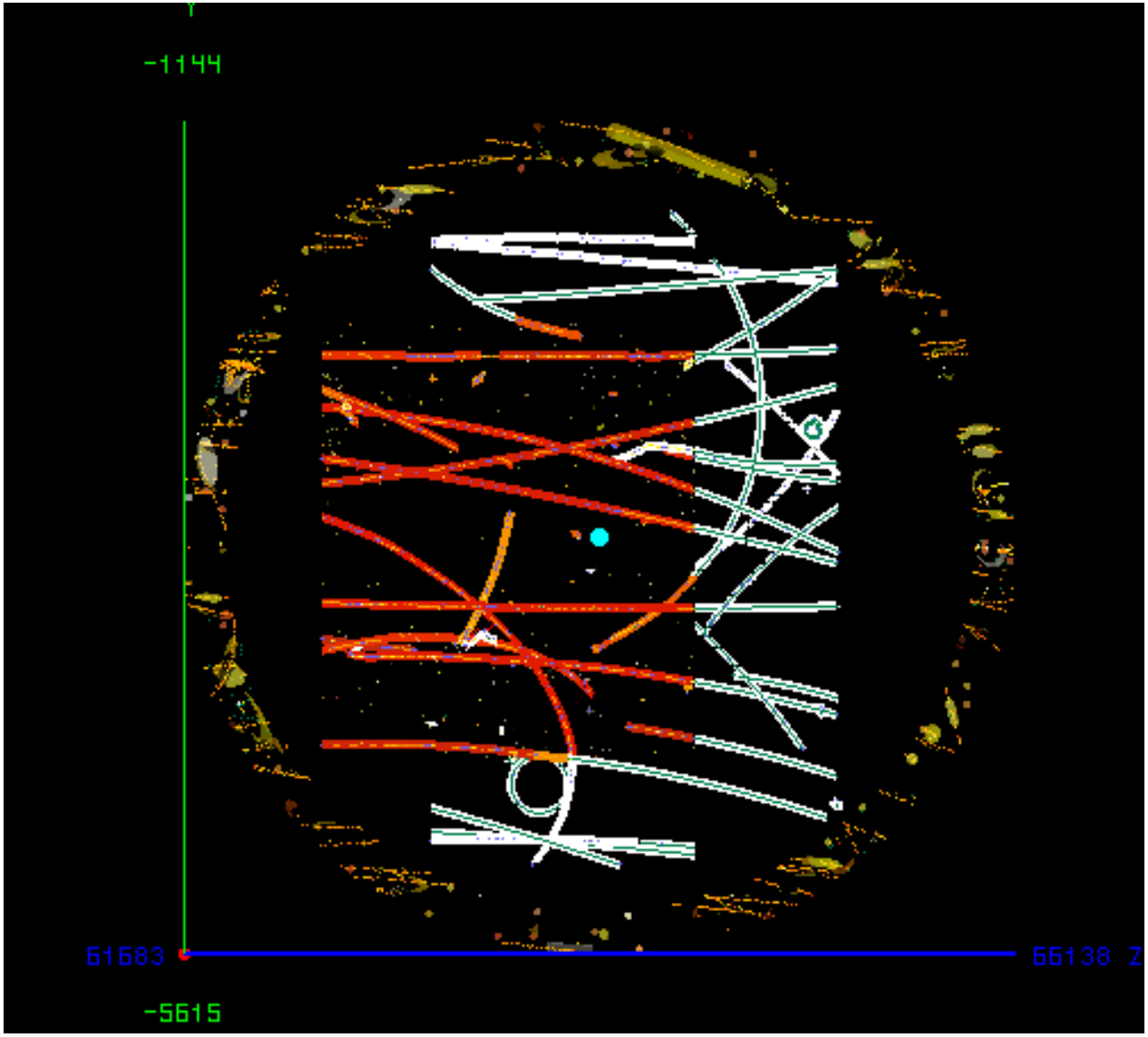
Cheats and Approximations

- Particle Identification
  - 3DST electron identification: based on particle type
    - Justified by T2K P0D electron id (>99%)
  - 3DST proton identification based on particle type (p < 900 MeV/c)
    - Justified by CERN SFGD beam test (clear dE/dX separation)
  - TPC electron identification based on particle type
    - Justified by T2K TPC performance
  - TPC proton identification based on particle type (p < 1.1 GeV/c)
    - Justified by T2K TPC performance
- Sign selection
  - TPC based on particle charge
    - Justified by T2K TPC performance and CERN beam test
  - 3DST based on measured curvature (no cheating)
- MIP Momentum
  - Based on particle momentum
    - TPC is justified by CERN beam test performance
    - 3DST is justified based on T2K range vs momentum performance

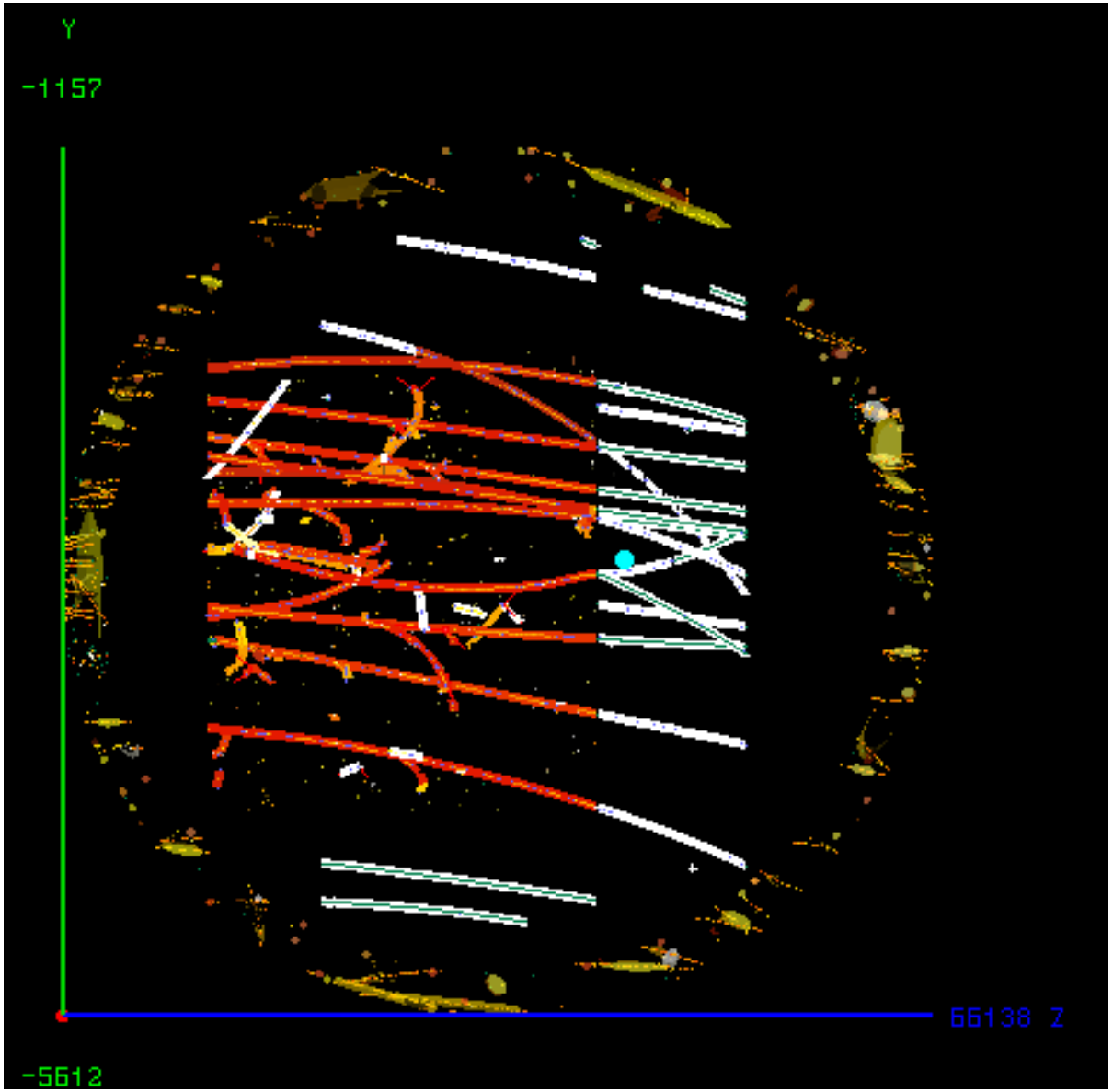
Reconstructed Full Spill Event



More Typical Full Spill Events



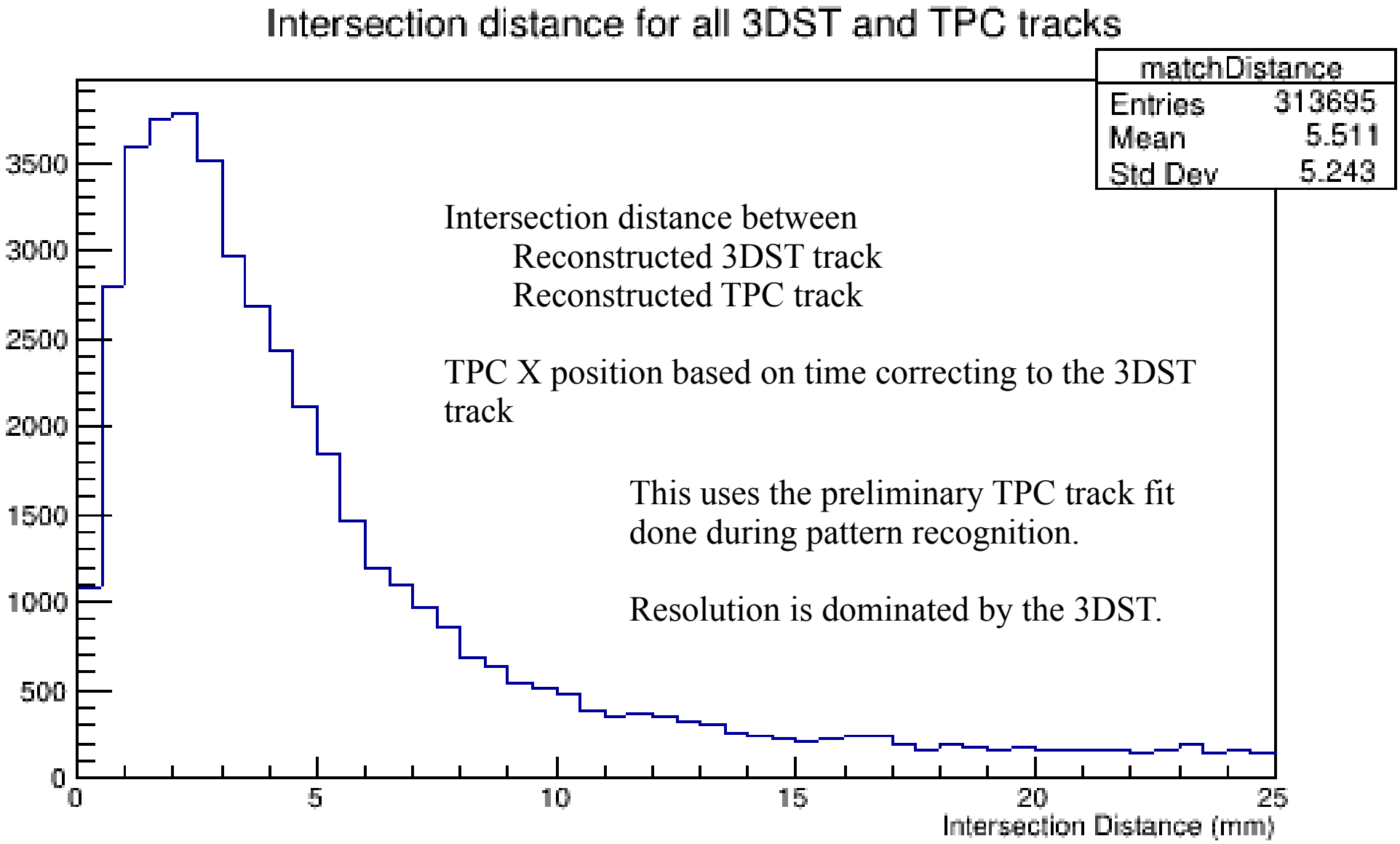
More Typical Full Spill Events



CC Inclusive Selection

- Select interaction candidates using a 50 ns time window
- Veto when there is activity in first 4 upstream 3DST layers (±50 ns)
- Interactions exiting the 3DST (activity in outer 4 layers of 3DST)
  - Do not consider TPC electrons and protons ($p < 1.1$ GeV/c)
  - Do not consider 3DST electrons and protons ($p < 900$ MeV/c)
  - Match 3DST & TPC tracks (connect within 15 mm & 45°)
  - For correct sign TPC tracks (neutrino→negative, antineutrino→positive)
    - Select highest momentum track
  - Selected track must start inside the 3DST fiducial volume
- Interactions fully contained in the 3DST (no activity in outer 4 layers)
  - Do not consider 3DST electrons and protons ($p < 900$ MeV/c)
  - Select longest correct sign track
    - Reject short tracks (Length < 30 cm)
  - Selected track must start inside the 3DST fiducial volume
- Assuming **no muon/pion** separation – background is largely from pions
  - We can expect some pion rejection using the ECal
    - Affected by track overlaps, so this requires more study
  - Expect muon/pion separation in 3DST based on track topology (not used)

3DST and TPC track matching



Intersection distance between
- Reconstructed 3DST track
- Reconstructed TPC track

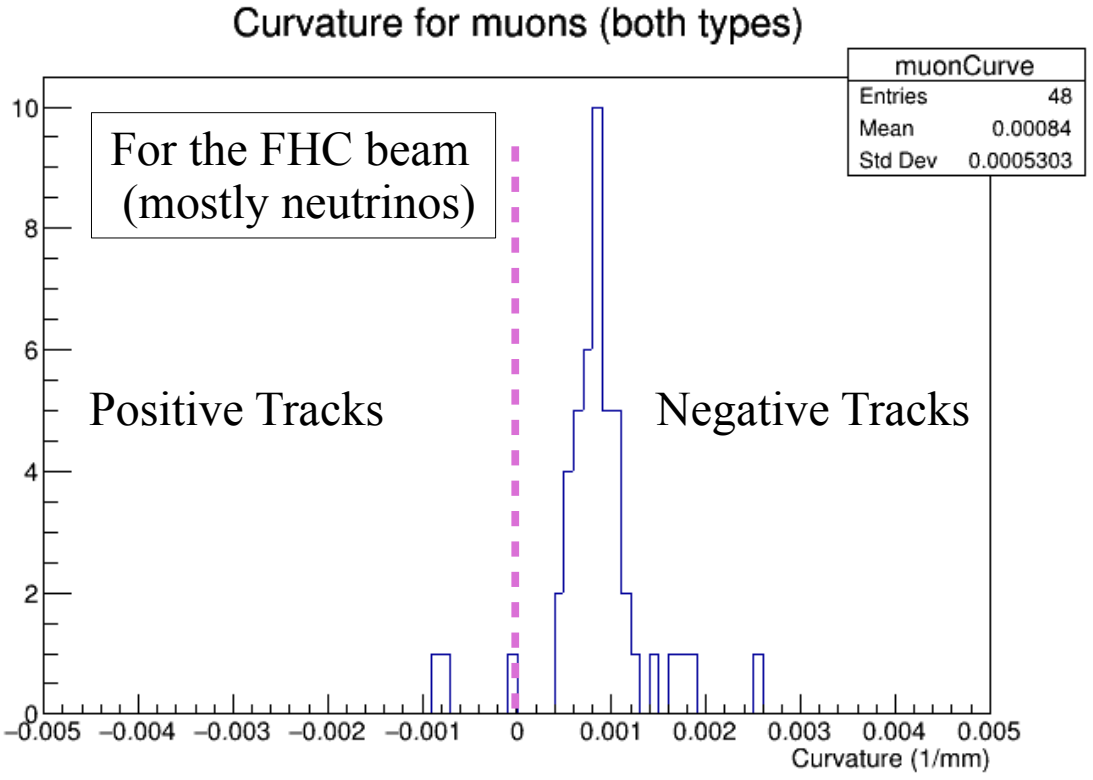
TPC X position based on time correcting to the 3DST track

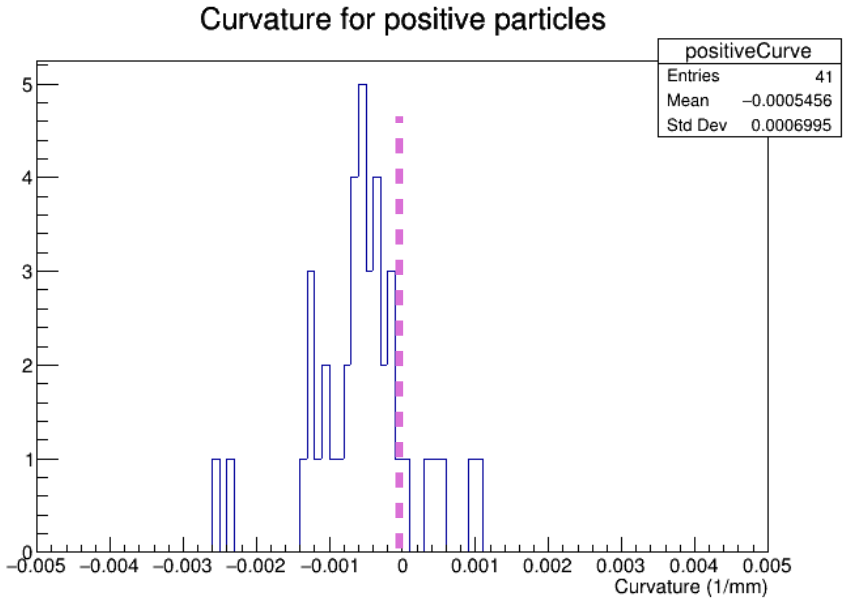
This uses the preliminary TPC track fit done during pattern recognition.

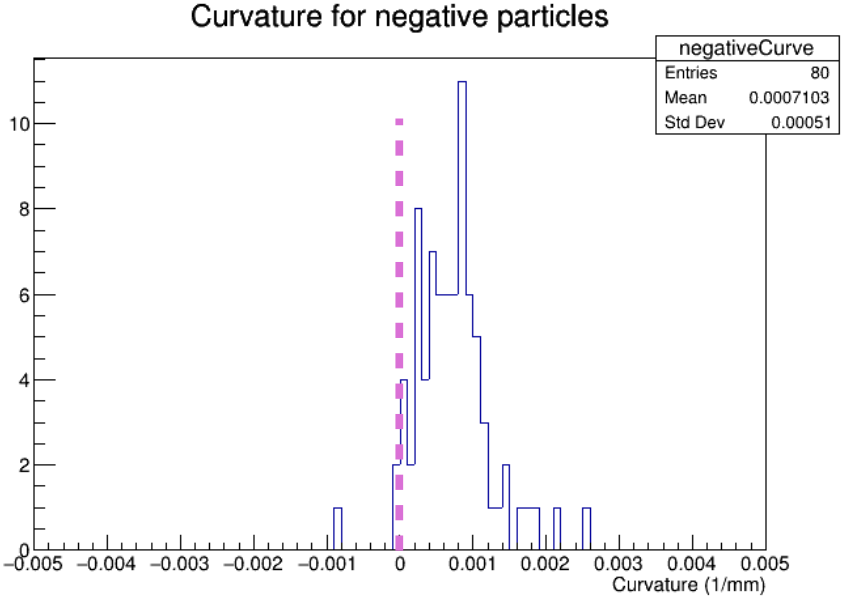
Resolution is dominated by the 3DST.

3DST Sign Selection

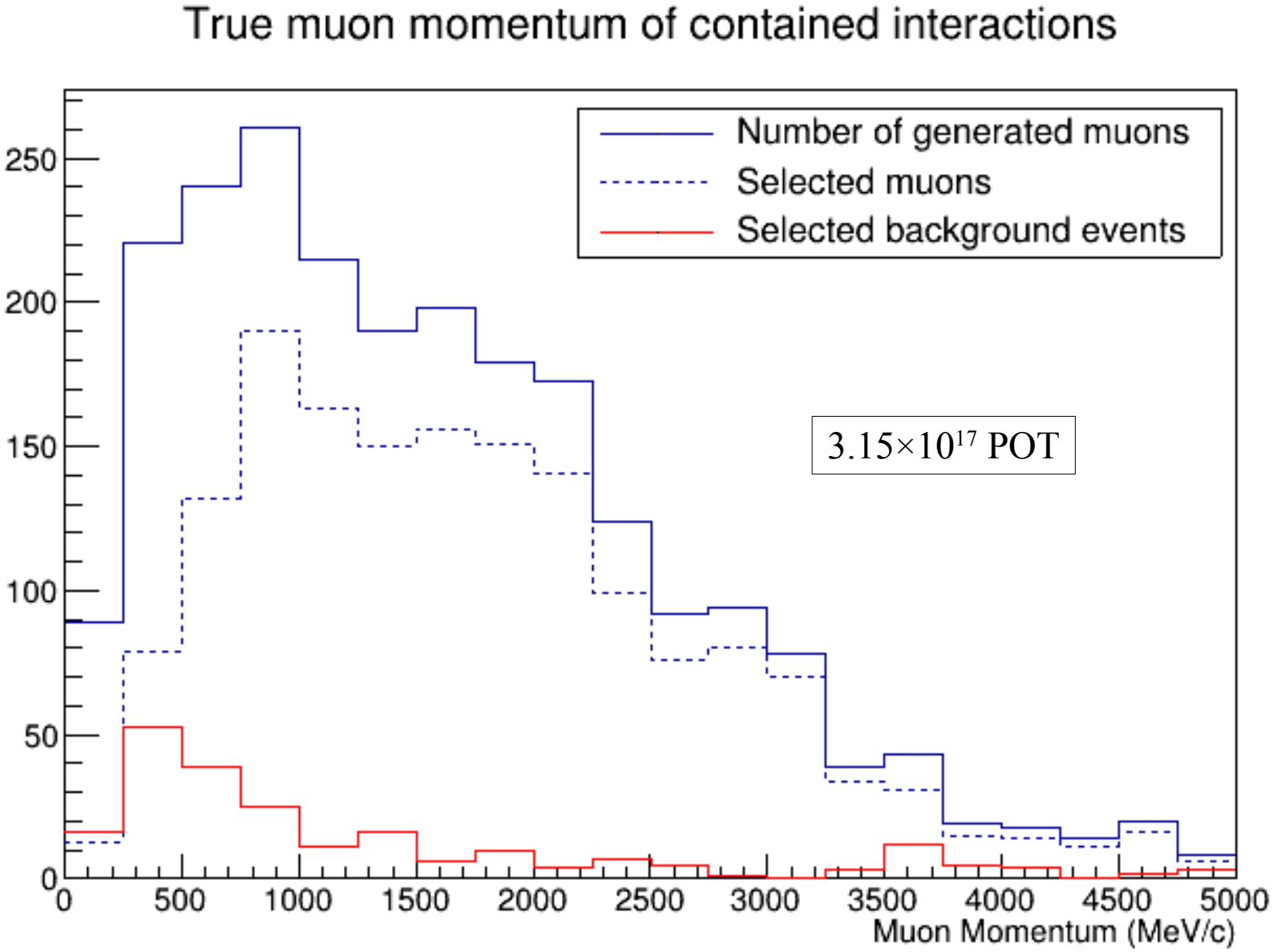
- Track sign calculated based
  - Direction sense from timing
  - Fitted direction at front and back
  - Length from track fit
    - Require length greater than 30 cm



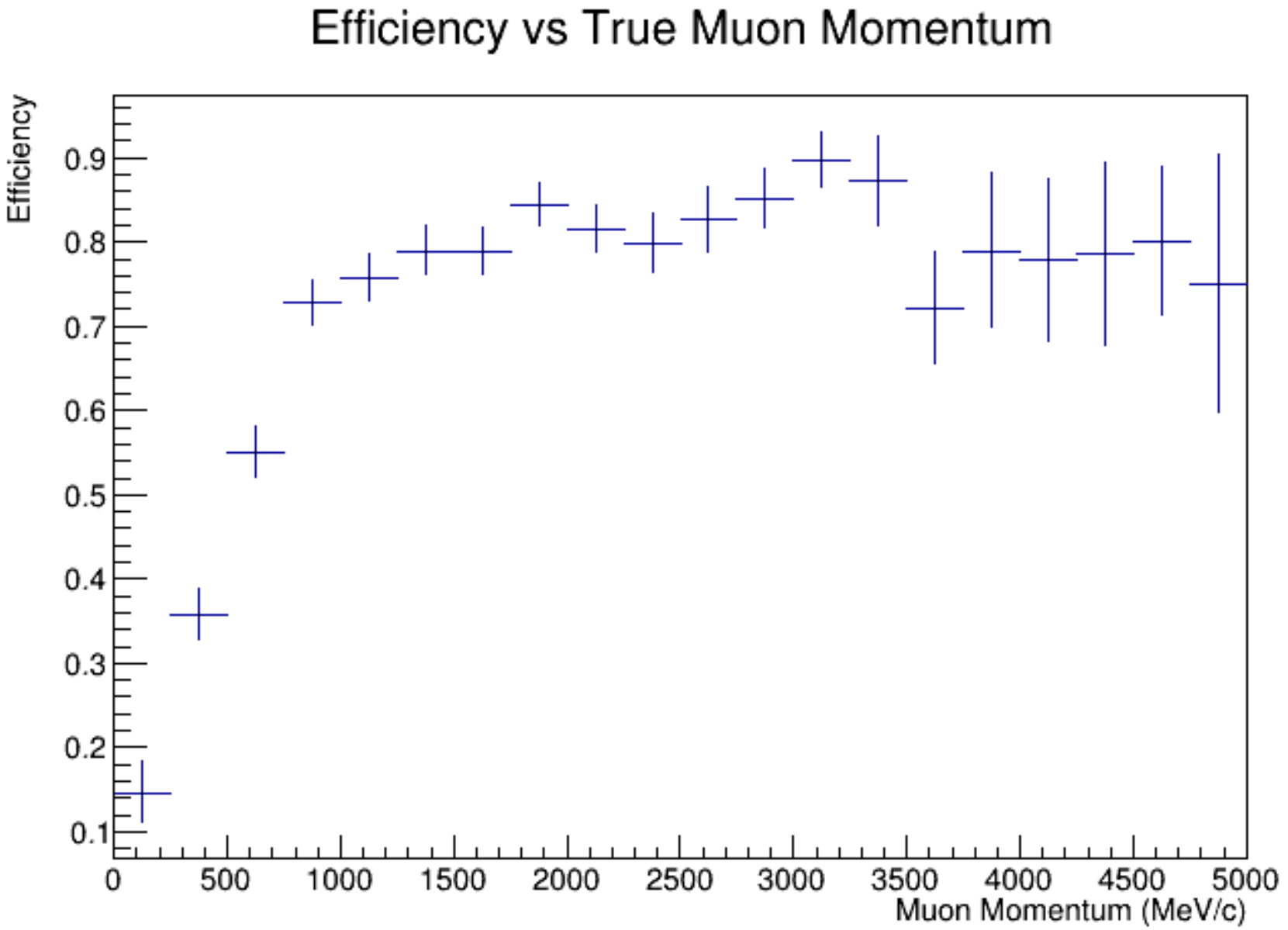




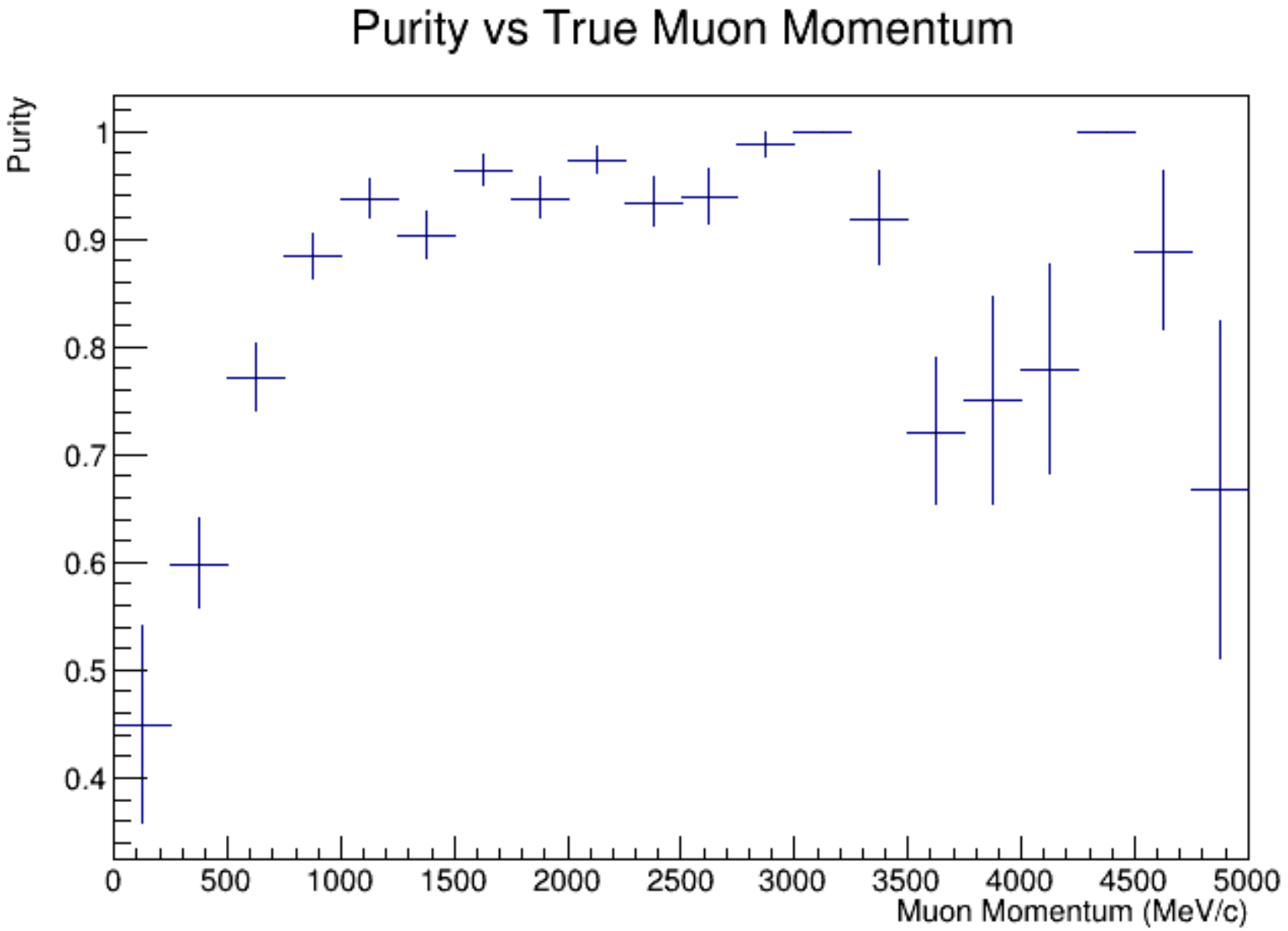
FHC μ^- Selection



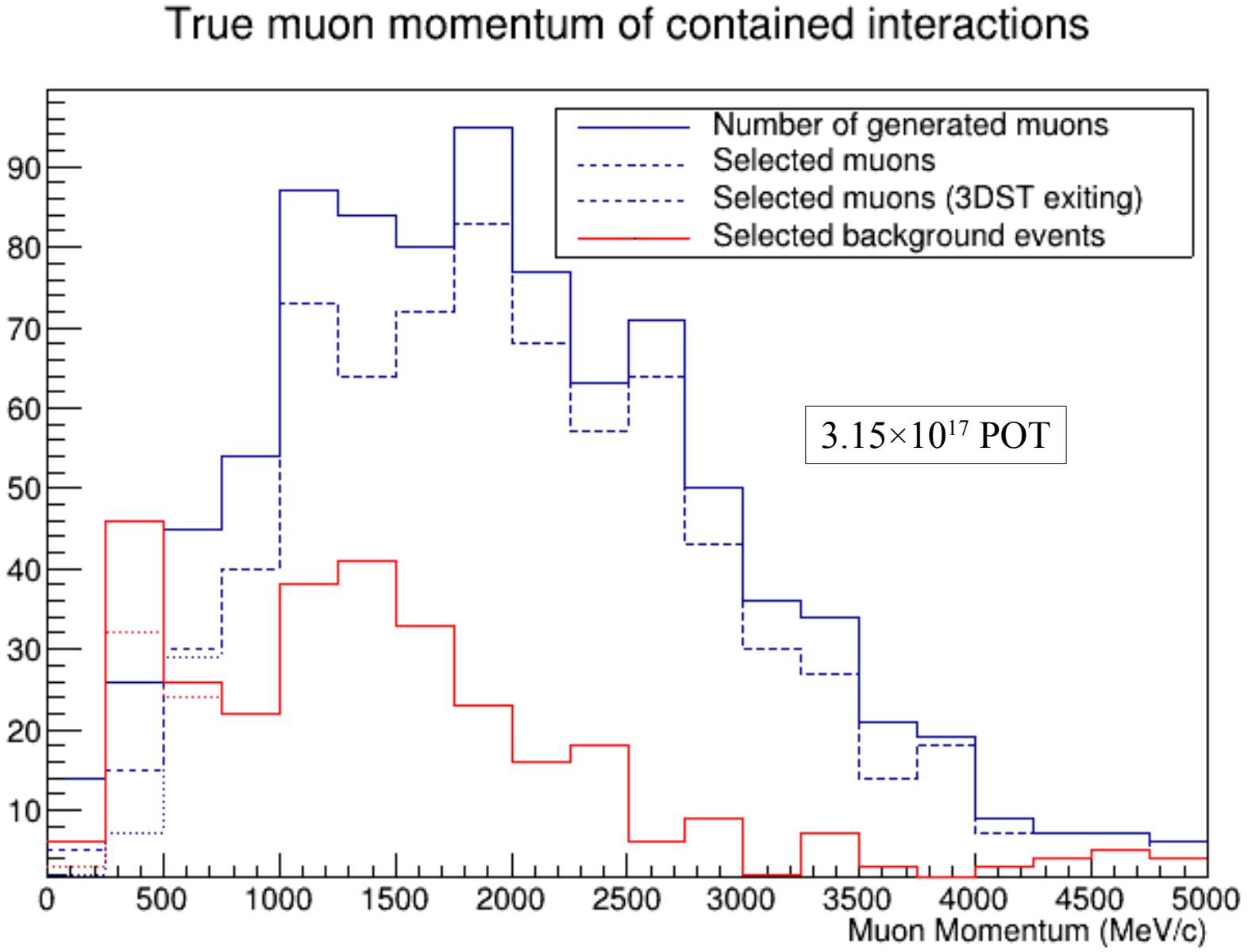
FHC efficiency to correctly select μ^-



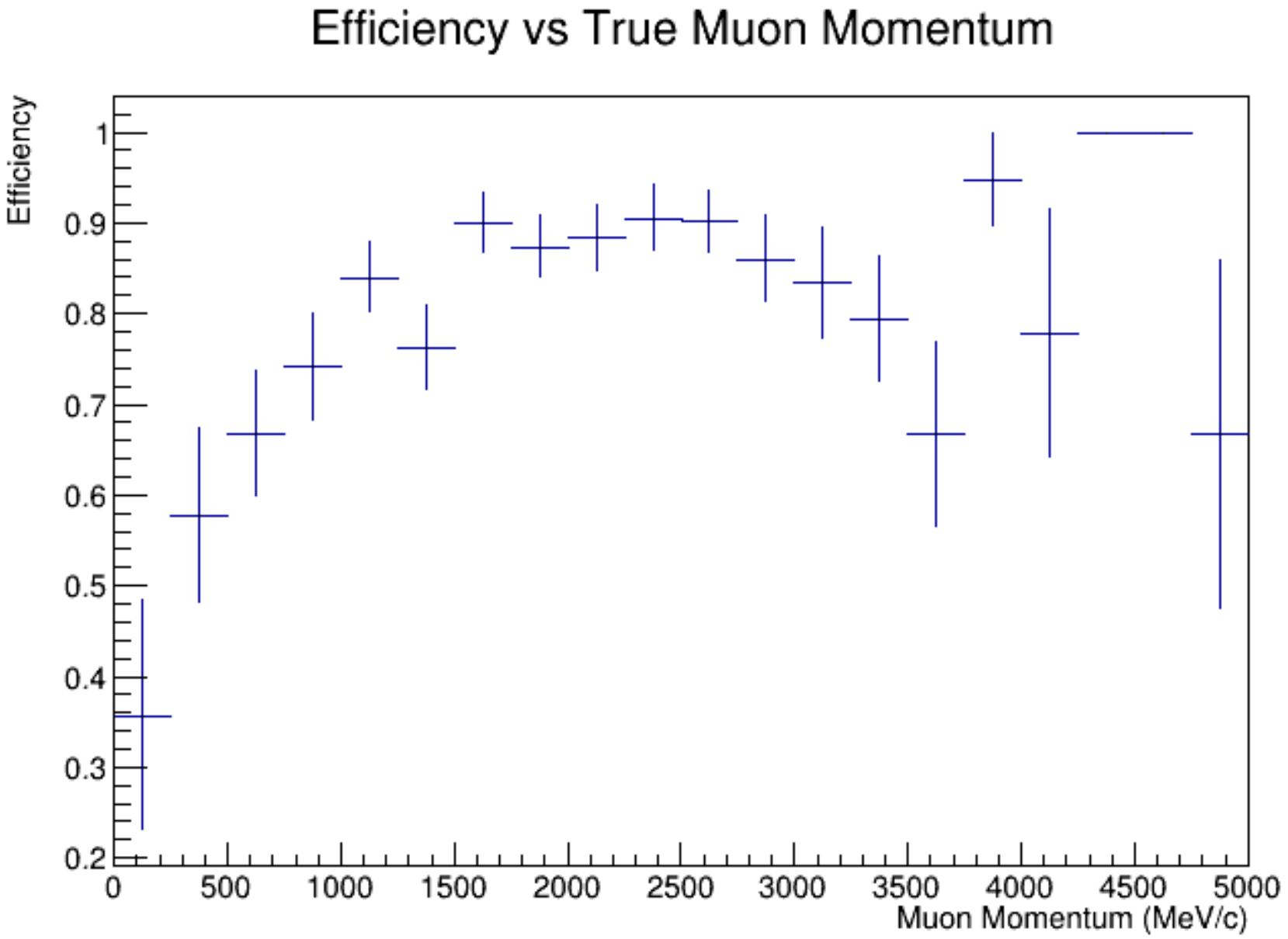
FHC μ^- Purity



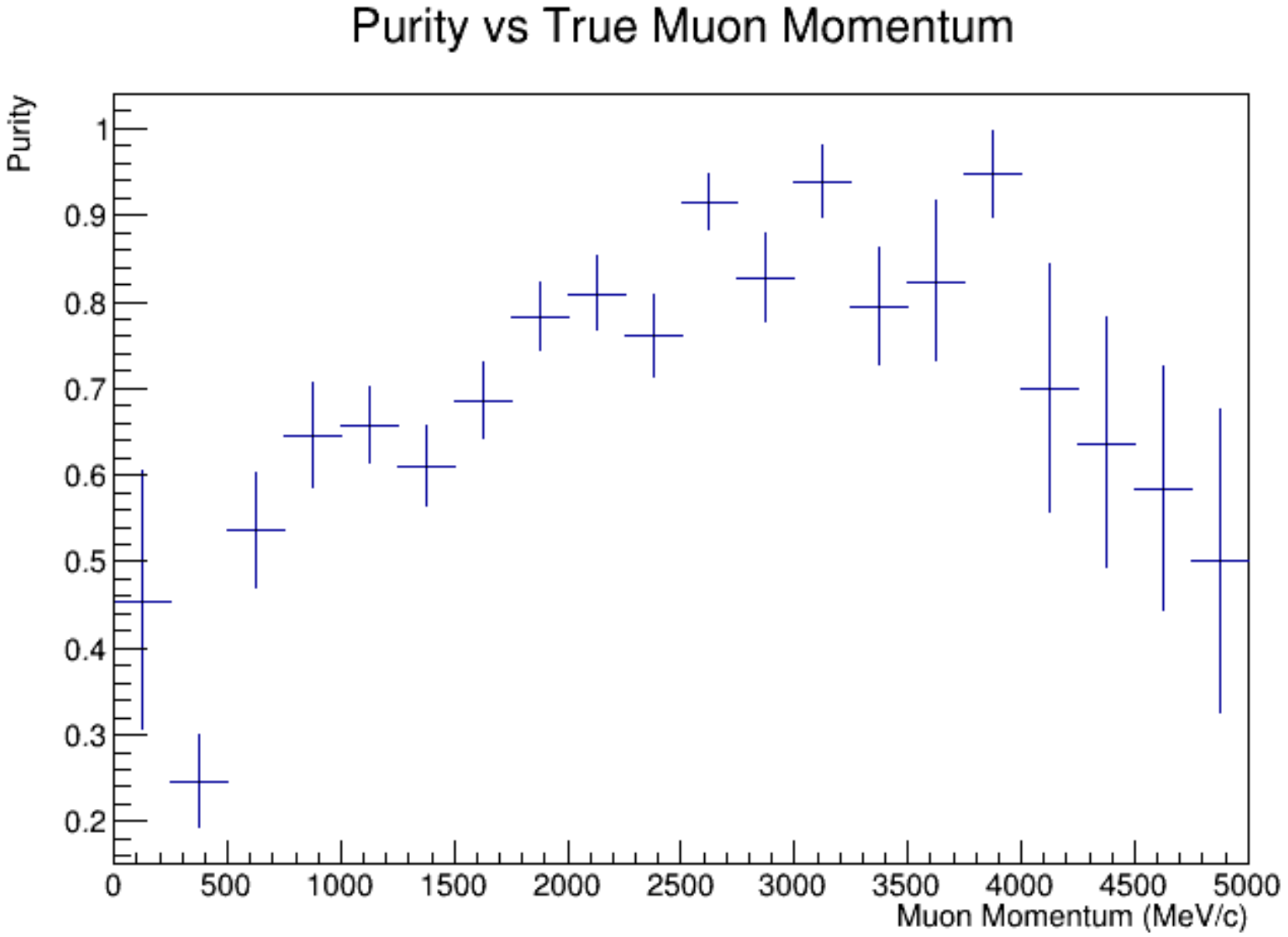
RHC μ^+ Selection



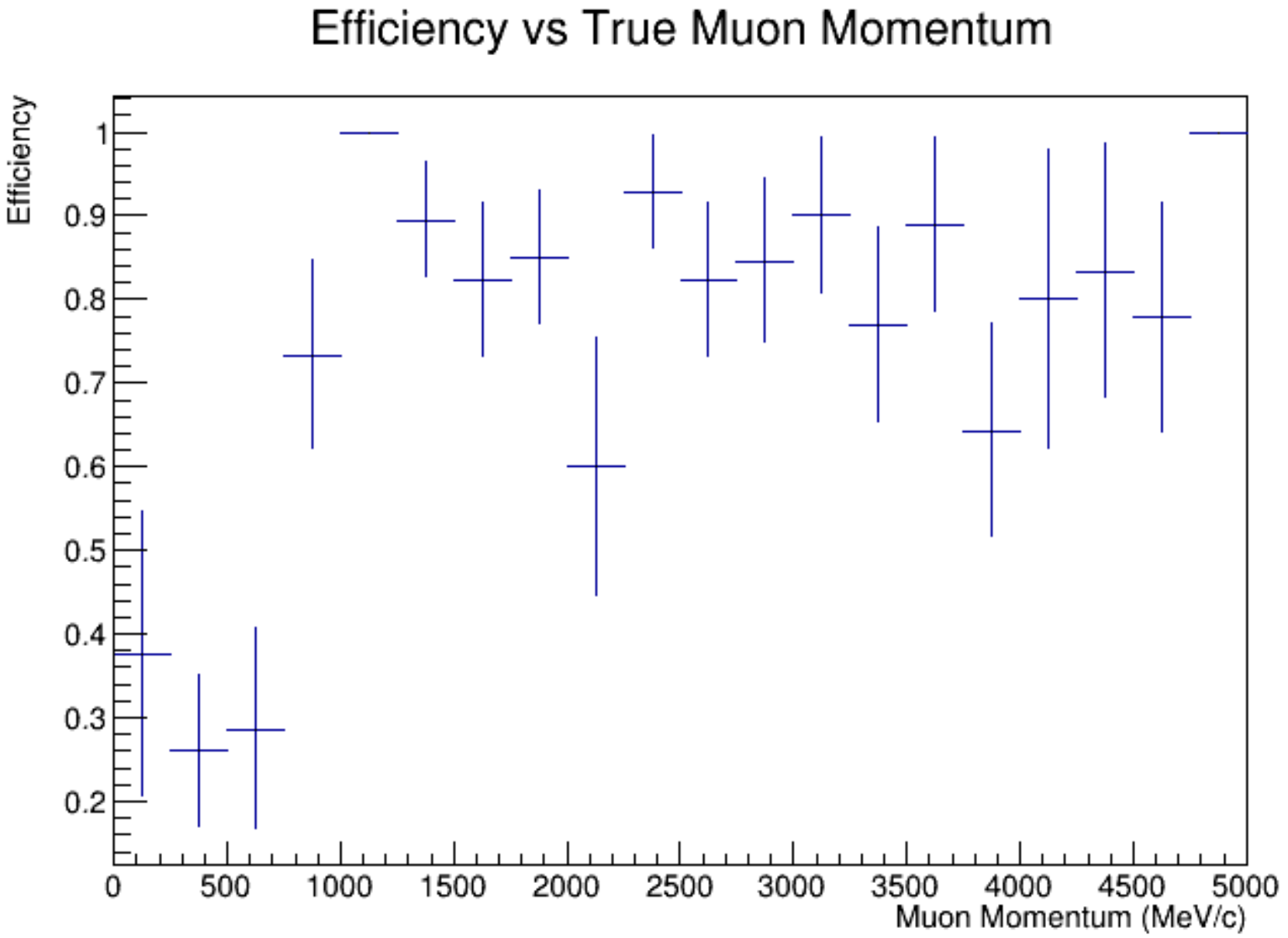
RHC efficiency to correctly select μ^+



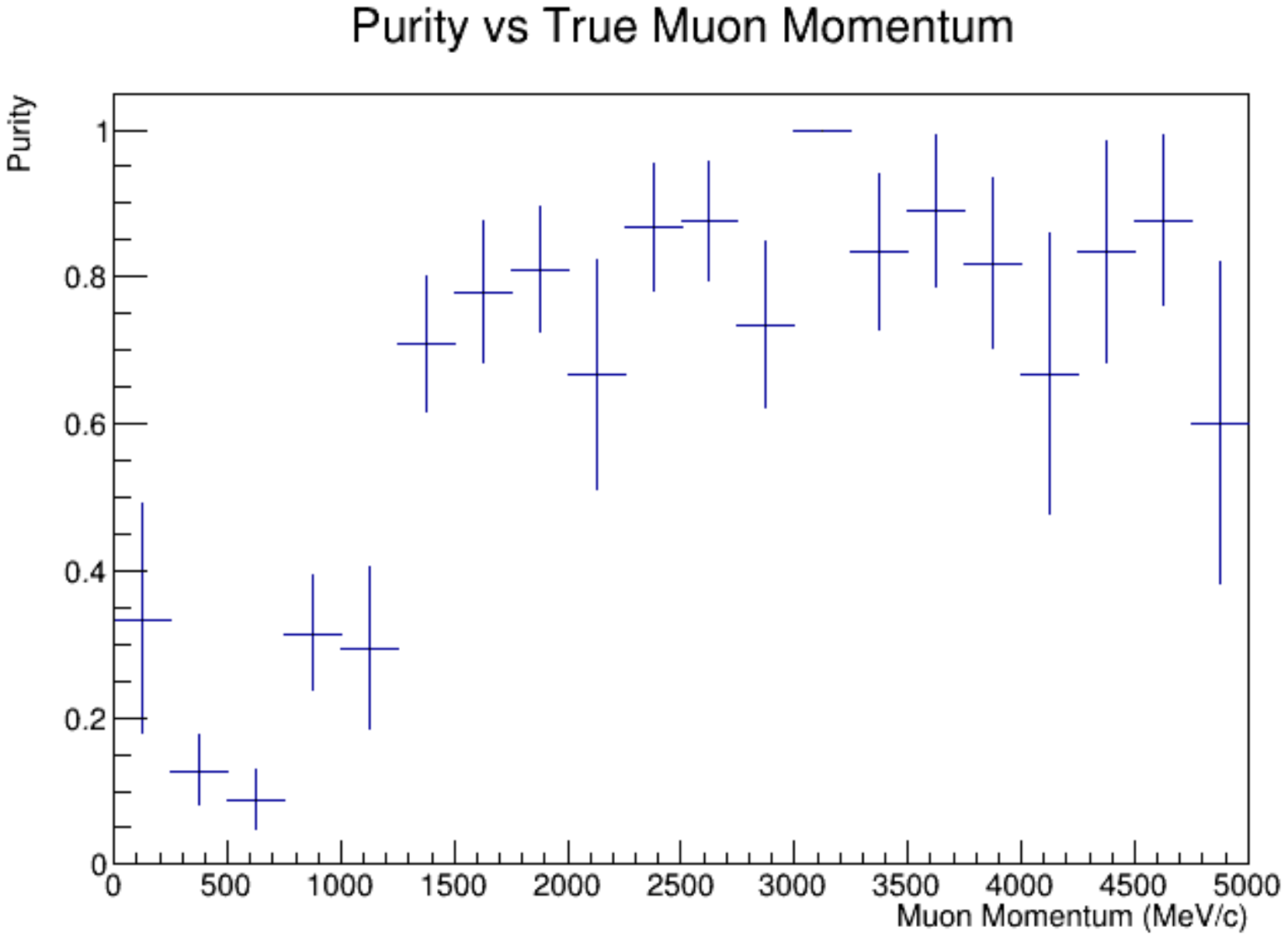
RHC μ^+ Purity



RHC efficiency to correctly select μ^-



RHC μ^- Purity



Summary and Conclusion

- A very simple selection for inclusive charged current interactions
  - The only significant cheat is PID, but its performance is based on existing detectors (T2K and CERN beam tests of the proposed TPC and superFGD)
  - Caveat: Momentum binning is large enough that resolution should be an insignificant effect, but resolution is ***not*** included.
- This is a **lower bound** for the expected efficiency and purity
  - It's a baseline of comparison for more sophisticated analyses
  - Dominated by single-pion, multi-pion, and DIS interactions
  - Efficiency to correctly select the μ^- in the FHC (neutrino) beam
    - Typical efficiency is 80%, but drops for muons below 750 MeV/c
    - Typical purity is 90%
  - Efficiency to correctly select the μ^+ in the RHC (antineutrino) beam
    - Typical efficiency is 80%, but drops below 750 MeV/c
    - Typical purity is 70%
  - For RHC μ^- (very limited sample)
    - Typical efficiency is 80% (above 1GeV)
    - Typical purity is 80% (above 1.5 GeV)
- Future directions: Quantify background sources
  - First look: Background interactions are mostly "correctly" selected by pion tracks with minimal external background (i.e. the muon is not the most energetic particle)

Backup Slides